Performance Test of gPhone (#123, #126, and #127) in Kyoto and ITB Jatinangor

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Performance Test of gPhone (#123, #126, and #127) in Kyoto and ITB Jatinangor

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Abstract. Gravity team of ITB, Kyoto University, and Kyushu University plan to carry out super hybrid measurement to monitor Carbon Capture Storage (CCS) injection in Gundih. During preparation stage and baseline survey before injection phase, gravity team analyze gPhone performance. Performance test of gPhone gravimeters in 2014 conducted in Kyoto and Jatinangor (three gPhone (#123, #126, and #127) placed in the same location). The tidal analysis program BAYTAP-G was used to decompose the gravity data into four components (tidal, trend, irregular, and response for auxiliary data). Response component in Kyoto relatively has lower frequency compare to Jatinangor, due to differences of the two measurement location. Response component from the longest time recording data (gPhone #123) give similiar pattern as gPhone #126, while gPhone #127 slightly different. Average standard deviation of the response component of three gPhone (#123, #126, and #127) respectively were 0.8, 1.0, and 1.9 µGal. Best drift achieved from this test show possibility to reach -4 to 5 µGal/day. Although gPhone #126 records different trend, but from tidal analysis comparison shows similiarity with gPhone #123.

1. Introduction

Gundih Carbon Capture Storage (CCS) project was started since 2012. Project stage already complete the evaluation study area in injection well and right now the project through the baseline monitoring survey stage. In this project, super hybrid gravity measurement and other geophysical methods prepared to monitor CO2 injection in the subsurface. Time-lapse microgravity can be applied to monitor mass increase and mass decrease due to significant activity in the reservoir. Simulation study on CCS injection [1] shows us that we will deal with weak signal of time-lapse microgravity. We need to be carefull and pay more attention in implementing super hybrid gravity measurement in Gundih CCS project. Super hybrid gravity measurement in the project will utilize three type of gravimeters, there are: continuous gravimeter (gPhone), absolute gravimeter (A10), and relative gravimeter (CG5).

During preparation stage of CO_2 injection, gravity team in this project carry out gPhone performace test for continuous measurement. There are three gPhone that were tested during 2014, in Kyoto and ITB Jatinangor. Understanding how to optimize gPhone performance will be usefull to estimate hydrological effect in Gundih area. Small drift of continuous gravimeter is very useful in ground water monitoring as shown in several studies [2] and [3]. Micro-g Lacoste as manufacturer of gPhone claim the capability of the instrument able to record continuous data with small drift (typically less than 500 µGal/month).

2. Observation

Gravity team already carry out five activites regarding Gundih CCS project. The activities since March 2013 until September 2014 conducted in Gundih, Bandung, and Kyoto. In March 2013, gravity team visited Gundih area to observe well location. In July 2013, gravity team carry out gravity observation and soil moisture meter installation. In January until February 2014, gravity team carry out gPhone and CG5 test in Japan (Kyoto University). After we packs the gPhone and CG5, the instrument moved to Indonesia. Since April until October 2014, performance test of gPhone conducted in ITB Jatinangor. Figure 1 shows the activity of gravimeter test and gPhone set-up in KYOTO-A and ITBj station.

(a) (b)

Figure 1. Activity of gravimeter test and gPhone set-up in: (a) KYOTO-A station and (b) ITBj station.

While collecting the following observations, we want to evaluate the intrinsic performance of the gPhone. We used the gMonitor software to record data every 1 second. Gravimeter test of three gPhone placed in the same location and we make sure the input parameter is the same for each gPhone. Several improvement are possible to be done from this test because the standard accessory pads to the leg of a gPhone sensor are not attached for three meter box, the level-checking procedure for the meter box might not have been optimized, vibrations from the electronics box mainly from the uninterruptible power supply (UPS) not yet suppressed.

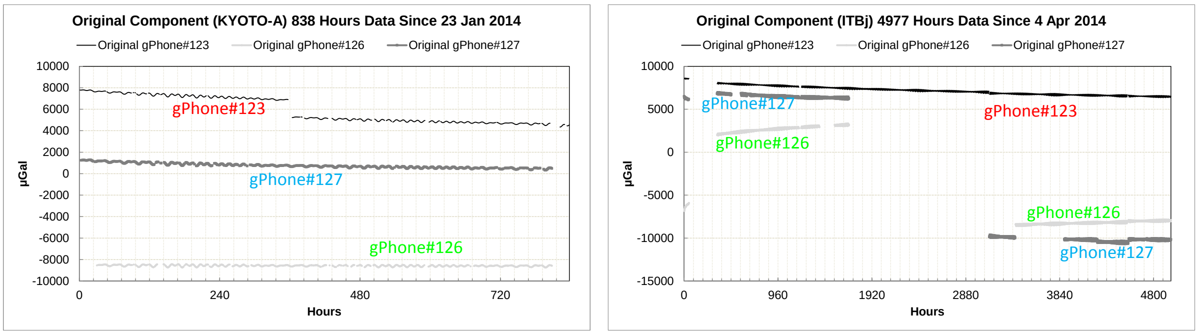
Started from 23rd January until 27th February 2014 gPhone #123, #126, and #127 record gravity every 1 second at Yoshida Campus-Rigakubu Building, Kyoto University. KYOTO-A station located at the coordinates 35.027°N and 135.787°E. We analyze 838 hours data from KYOTO-A station. The original component from three gPhone tend to record decreases value. Based on figure 2a, gPhone #123 and #127 ranged in positive value, while gPhone#126 ranged in negative value. Original component range for gPhone #123, #126, and #127 respectively are (4346 to 7802) µGal, (-8732 to -8431) µGal, and (326 to 1292) µGal. Significant step shows in gPhone#123 original component. At glance, gPhone#126 relatively flat compare to the other two.

Three gPhone delivered from Japan to Indonesia for about a month process. We started again the performance test on 4th April 2014 in ITB Jatinangor GSG Building. ITB Jatinangor is about 21 km away from ITB main campus and can be reach approximately with in an hour by car. ITBj station coordinate is 6.925°S and 107.768°E. GSG building of ITB Jatinangor permitted to be used for gPhone test from 4th April until 28th October 2014.

We analyze 4977 hours data from ITBj station. The original component from gPhone #123 and gPhone #127 tend to record decreases value, while gPhone #126 tend to record increases value. We notice the performance from gPhone #126 shows unexpected reverse trend since mobilisation from Japan to Indonesia. Based on figure 2b, original component range for gPhone #123, #126, and #127 respectively are (6336 to 8641) µGal, (-8600 to 3339) µGal, and (-10676 to 6964) µGal. At closer look, significant step shows again in gPhone #123 original component.

During April-October 2014, several times gPhone recording needed to be restarted because several issues. Data recording in ITBj experienced failure of power supply. Two UPS of gPhone also needed to be repaired. Here several notes from gPhone data recording at ITBj:

1. Broken UPS of gPhone #126 unit (April 2014) – repaired by replacing the storage battery.
2. Broken UPS of gPhone #127 unit (July 2014) – after replacing the fuse and still not working, UPS unit replaced with the new one.
3. At the end of October 2014 we need to move the station to ITBjm.
4. Data recording in gPhone #123 relatively last longer and more continuously compare the other two gPhone, while gPhone #127 is the most frequent to be restarted.
5. After that, in November 2014 gravity team moved the station in the room close to mushola of ITB Jatinangor (about 500 meters from previous location). Figure 3 shows the activity of gravimeter test and gPhone set-up in ITBjm station.



(a) (b)

Figure 2. Original component from: (a) 838 hours data in KYOTO-A station and 4977 hours data in ITBj station.

Figure 3. Activity of gravimeter test and gPhone set-up in ITBjm station.

To describe the intrinsic performance of gPhone, we present the summary of gPhone's comparison. The comparison of sensor temperature from gPhone #127 is slightly higher compare the other two. The comparison of sensor pressure from gPhone #123 is more stable compare the other two. Two gPhone (#126 and #127) record significant step down pressure after restart in the middle of July 2014. Special case of gPhone #127 records distinct step of sensor pressure after restart in the middle of August 2014. We also observe jumping value for beam position in the middle of October 2014. Intrinsic of gPhone #127 has reverse condition compare to the other two gPhone. Beam position of gPhone #127 relatively close to the -1 AD, while gPhone #123 and #126 close to the 1 AD. Two gPhone (#126 and #127) have higher level correction during data recording in the middle of July until middle of August 2014. Higher variation of level correction for gPhone #127 recorded compare to the other two. Level correction from gPhone #127 also shows jumping value at the end of September until early October 2014. Ambient pressure and ambient temperature variation from each gPhone relatively records similliar trend although not exactly the same value. This condition, little bit strange because the location of gravimeter test is set up in the same room (about 3 μGal different of barometer compensation can be calculated for each gPhone).

3. Data Analysis

Tidal analysis of gPhone data in ITBj was processed using BAYTAP software [4]. The tidal analysis program BAYTAP-G was used to decompose the gravity data into four components (tidal, trend, irregular, and response). Comparison of tide, response, trend, and irregular component from KYOTO-A and ITBj station shown in figure 4 and figure 5.

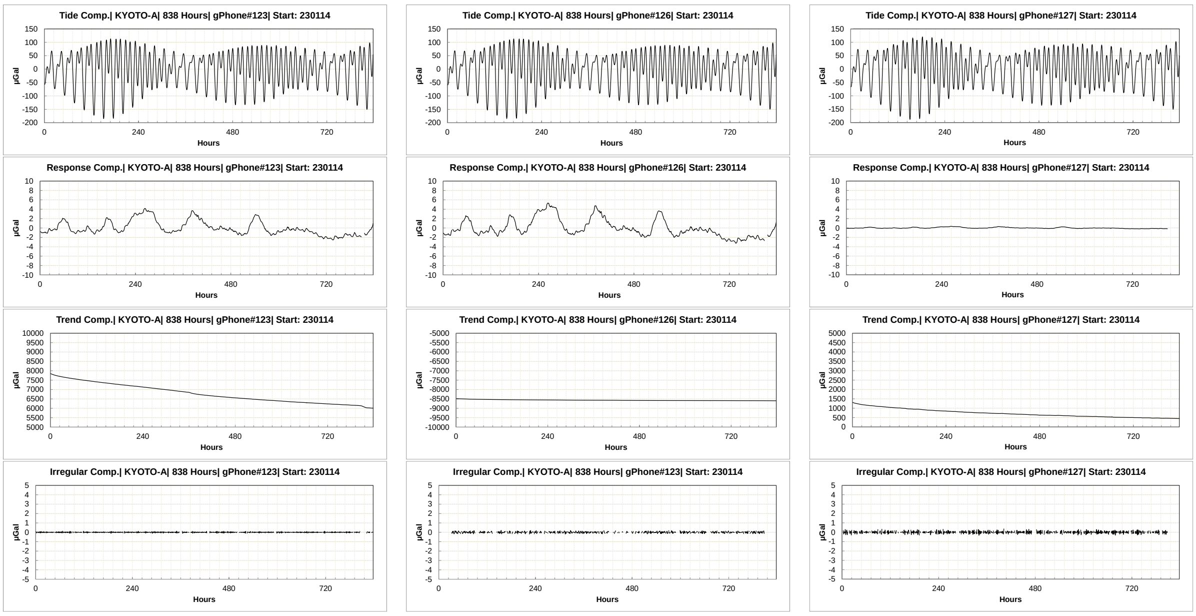


Figure 4. Comparison of original, tide, response, trend, and irregular component from KYOTO-A station.

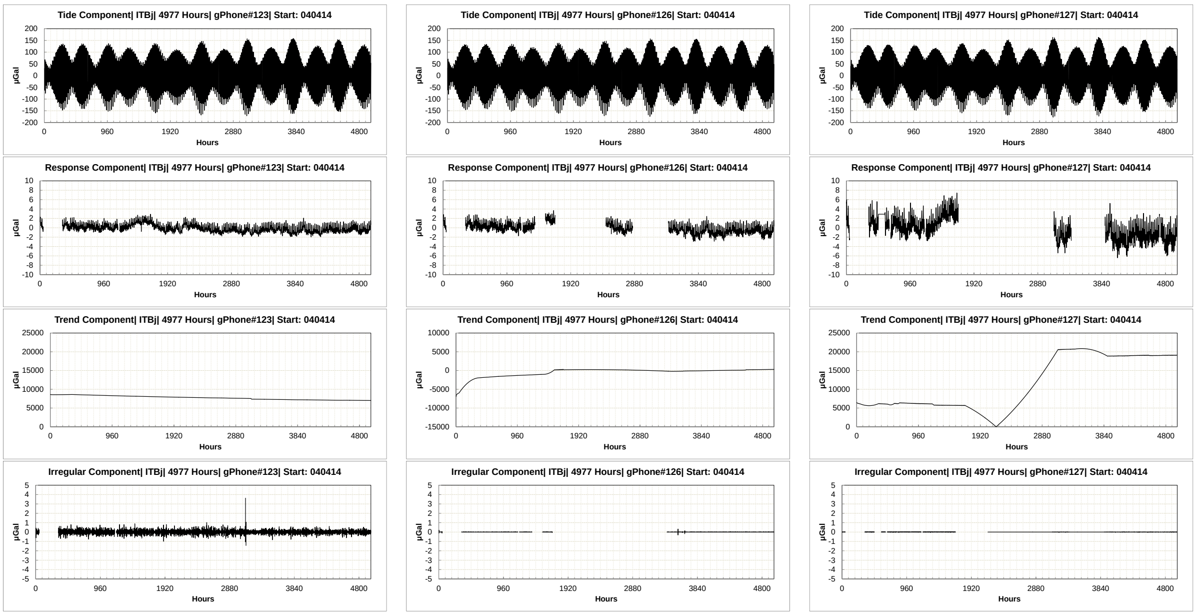


Figure 5. Comparison of original, tide, response, trend, and irregular component from ITBj station.

In this analysis we focus on the response component that resulted from BAYTAP calculation. We conducted several calculation using BAYTAP wih different time span parameter because our data from three gPhone have different continuity (as mention earlier in ITBj observation). Different input data numbers provides us the descriptive statistics from average value of monthly response. Number of BAYTAP calculation for each month shown in figure 6a. Most of mean value for each month as shown in figure 6b are smaller than ± 2 µGal, except from gPhone #127 data in June - July 2014. Standard deviation as shown in figure 6c smaller than 4 µGal for all gPhone and we can also observe gPhone #123 relatively similar with gPhone #126. Negative value of gPhone data (figure 6d) recorded up to -3 µGal and positive value of gPhone data (figure 6e) recorded up to +5 µGal. Recorded data of gPhone as shown in figure 6f is the information of range data. The observation data dominated in the range up to 10 µGal, except from gPhone #127 in April, July, August, September, and October. Additional note from figure 6 is we have no data recording during March 2014 (due to shipping of the instrument from Japan to Indonesia).

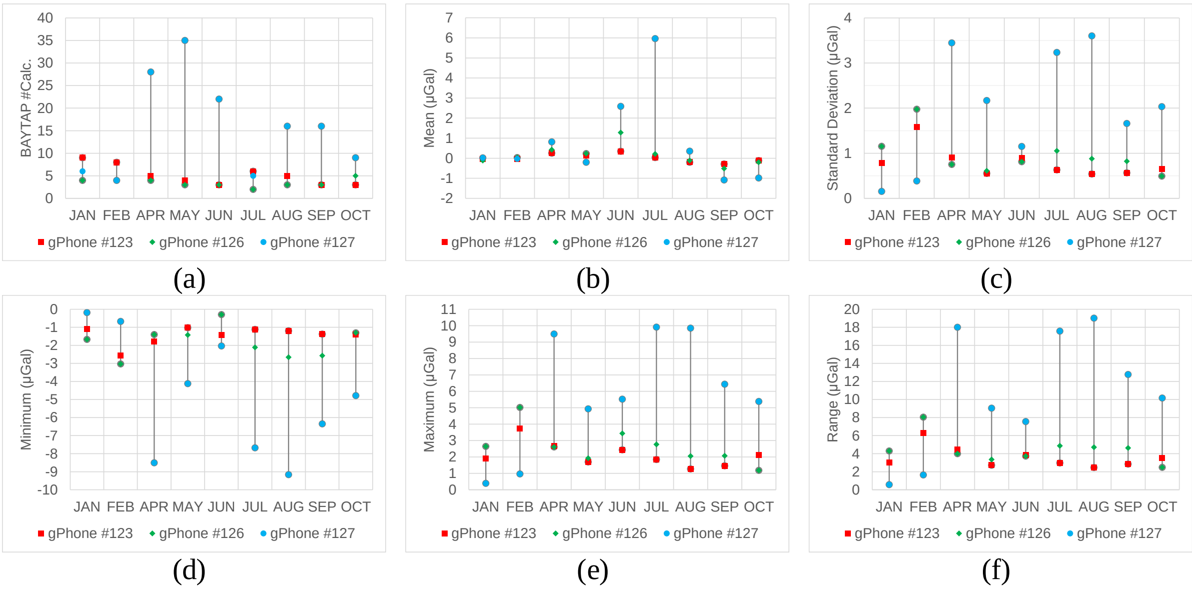
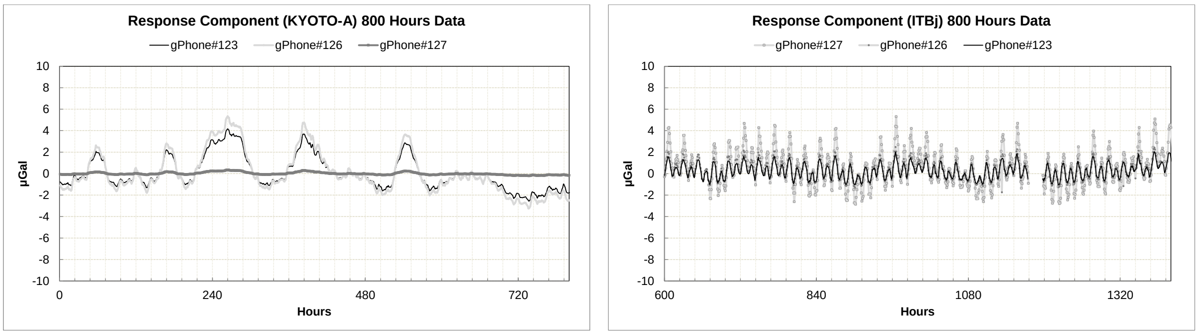


Figure 6. Descriptive statistics comparison of monthly response component: (a) number of calculation using BAYTAP, (b) mean, (c) standard deviation, (d) minimum, (e) maximum, and (f) range.

Closer look at response component from 800 hours data sample from KYOTO-A and ITBj station are shown in figure 7. Different patern of response component between KYOTO-A (figure 7a) and ITBj (figure 7b). Response component in Kyoto A relatively has lower frequency compare to ITBj. Response amplitude from gPhone #123 relatively similar as gPhone #126. Visualization plot and descriptive intrinsic performace of gPhone #127 confirm different character in response component. Response component from gPhone #127 gives smaller amplitude during KYOTO-A observation but gPhone #127 gives higher amplitude during ITBj observation. Average standard deviation of the response component of three gPhone (#123, #126, and #127) respectively were 0.8, 1.0, and 1.9 µGal. The differences in measurements of gravity response of Kyoto and Jatinangor means that nothing is wrong with the gphone instruments, but merely due to differences of the two measurement location. Kyoto is located in the midle latitude, while Jatinangor is relatively low latitude. We suspect pressure tide component gives stronger effect during gPhone observation.

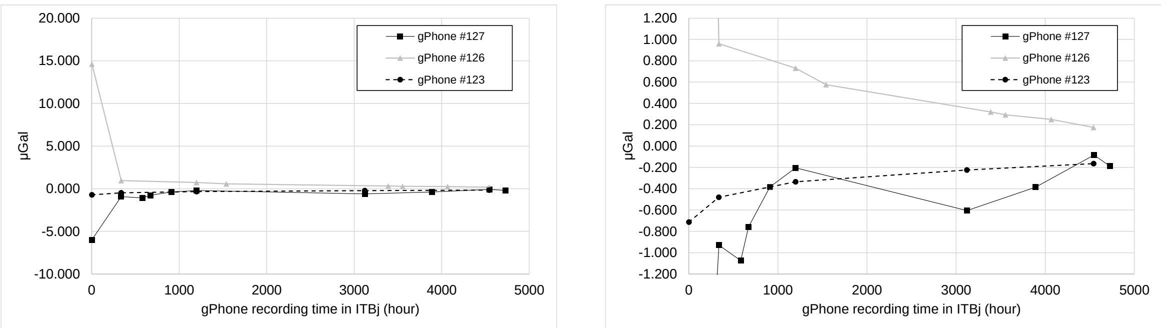


(a) (b)

Figure 7. Comparison of response component from 800 hours sample data: (a) KYOTO-A station and (b) ITBj station.

Further improvement already conducted since September 2015. We try to check the level correction for three gPhone, and then we change the input for level correction constant based on gPhone Micro-g Lacoste procedure. There is no significant change for level correction constant of gPhone #123 and #126, while level correction constant of gPhone #127 need to be corrected based on Micro-g Lacoste software calculation. Based on our latest data processing (discussed in March 2016) gPhone #127 shows similarity trend.

Evaluation of gPhone drift shown in figure 8. Each time gPhone started records data, drift of gPhone also changes. Drift of gPhone is getting smaller along time of data recording. Each gPhone records biggest drift at the first time of data recording. Comparison from figure 8 show us that two gPhone have negative drift, while gPhone #126 is the only one with positive drift. Best drift achieved for gPhone #123, #126, and #127 respectively are -0.165 µGal/hour, 0.175 µGal/hour, and -0.085 µGal/hour. In other words, the sensor drift rates from gPhone test possible to reach -4 to 5 µGal/day.



(a) (b0

Figure 8. Drift (µGal/hour) comparison: (a) full view of Y-axis, (b) zoom-in view within the Y-axis range -1.2 until 1.2 µGal.

4. Tidal Analysis and Comparison Study

We made tidal analysis from ITBj data recordings. The compatible data were filtered and resampled to obtain a 1-hour interval data set and the tidal analyses were made by employing "BAYTAP-G" software for short period waves. The output from BAYTAP-G calculation (at ITBj) for each gPhone shown in table 1. The output of gPhone #123 gives negative value of minimum ABIC and smaller error compare the other two gPhone.

We made comparisson between ITBj tidal analysis and the results superconducting gravimeters (SG) measurement [5]. Brief comparison study information for tidal analysis explained in table 2. Although two stations (ITBj and DG0) have more than 14 km apart, we still consider the tidal analysis results from SG data recording in 1999-2003 as refference because relative precision of 0.18% tidal analysis [5].

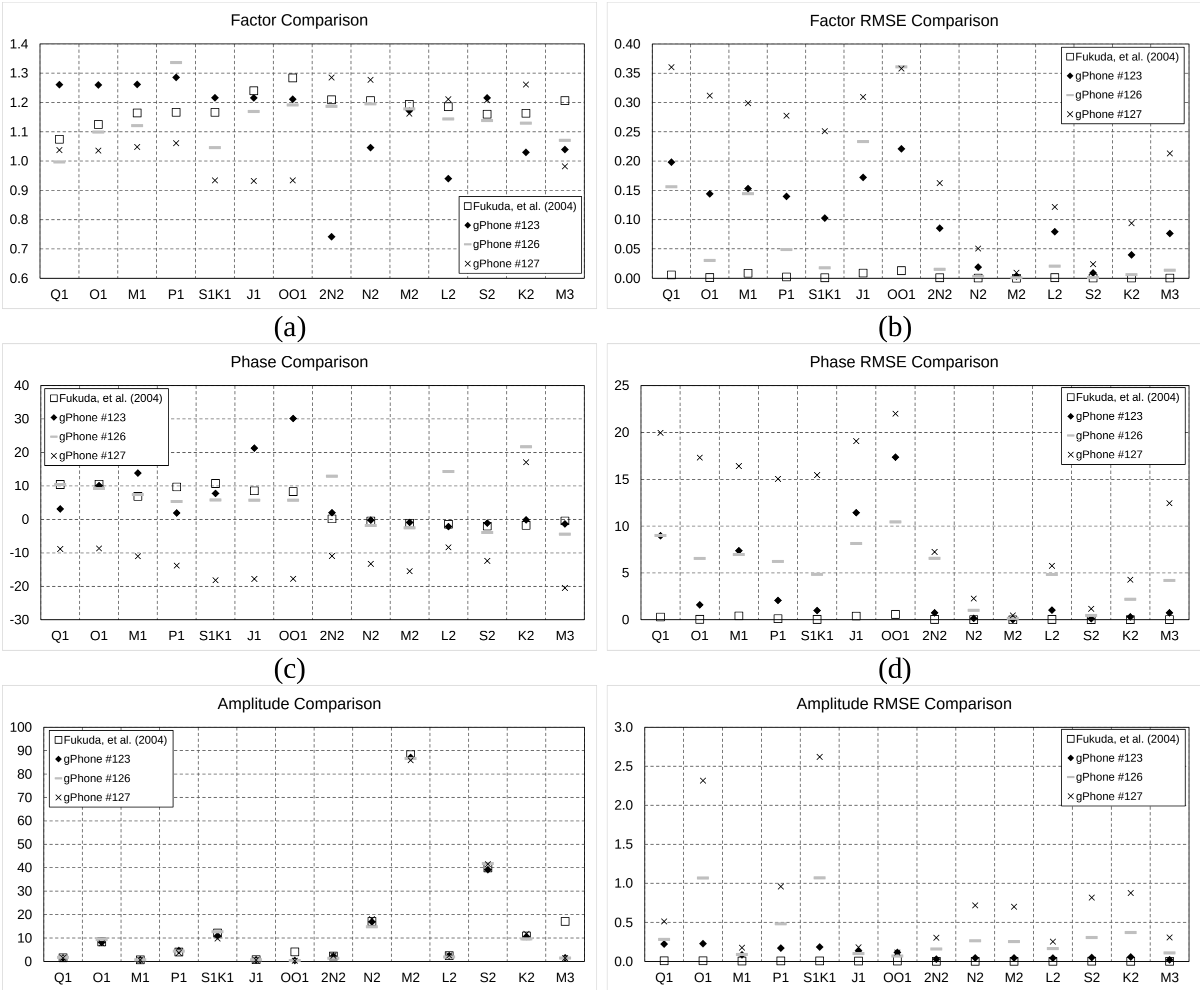
Table 1. BAYTAP-G output comparison for 4977 time span (at ITBj).

BAYTAP-G OUTPUT	gPhone #123	gPhone #126	gPhone #127
Data range ratio	240.830	1220.700	1860.700
Mean value	929.060	927.650	932.910
Data removed	5	0	8
Minimum ABIC	-917.970	5291.250	9818.020
Attained at Vmin	0.640	0.057	0.028
SD	0.348	0.139	0.181
Respc	-0.537	-0.675	-1.461
Error	0.046	0.150	0.405
SQE	0.121	0.019	0.033
Available	4652/4977	2798/4977	2576/4977

Table 2. Brief comparison study information.

Comparison Study	SG Calibration [5]	2014 gPhone test (this study)
Instrument	SG	gPhone
Specification	drift ≤ 0.5 μGal/month noise 0.3 μGal/v(Hz) resolution 0.01 μGal	drift ≤ 500 μGal/month noise 3.0 μGal/v(Hz) resolution 0.1 μGal
Observation	1999/02/28 to 2003/09/01	2014/04/04 to 2014/10/28
Station	Geological Museum	ITBj
Coordinate	(-6.9083, 107.0250, 718)	(-6.9250, 107.7680, 800)
Software	BAYTAP-G & BAYTAP-L	BAYTAP-G

Figure 9 ploted with X-axis as 14 tidal groups (Q1, O1, M1, P1, S1K1, J1, OO1, 2N2, N2, M2, L2, S2, K2, M3). The results from SG calibration plotted as (□) as refference for gPhone #123, #126, and #127 that plotted respectively as (♦), (-), and (×). Factor of M2 group from 2014 gPhone performace test slightly smaller compare to SG tidal analysis, while the other factor for others group show more wide discrepancy (figure 9a). Phase comparison (figure 9b) that ranged in ± 2° phase different of gPhone #123 and gPhone #126 respectively are 57.1% groups and 42.9% groups, while gPhone #127 shows more than ± (6-29)° phase different. Amplitude comparisson (figure 9c) of gPhone #123, gPhone #126, and gPhone #127 that have less than ± 1 μGal different respectively are 71.4% groups, 50.0% groups, and 57.1% groups. We also can see the comparison of RMSE from SG data recording in 1999-2003 is smaller compare to 2014 gPhone performace test (figure 9b, 9d, and 9f).



(e) (f)

Figure 9. Comparison of tidal analysis between Fukuda et al. (2004) and 2014 gPhone performace test.

5. Conclusion

We completed gPhone performace test in Japan and Indonesia during 2014. We evaluate intrinsic performace of gPhone #123, #126, and #127. From the test so far, we can see three gPhone recording experienced several interuption which need to be considered before we install continuous measurement in CCS injection area.

Response component in Kyoto A relatively shows lower frequency compare to ITBj. And overall, response component from gPhone #123 relatively give similar patern as gPhone #126. As we can see from descriptive of intrinsic performace, gPhone #127 slightly different in response component. Average standard deviation of the response component of three gPhone (#123, #126, and #127) respectively were 0.8, 1.0, and 1.9 μGal. The differences in response frequency merely due to differences of the two measurement location.

Best drift achieved from this test show possibility to reach -4 to 5 μGal/day. The sensor drift of gPhone #123 and gPhone #127 have negative drift, while gPhone #126 is the only one with positive drift. Although gPhone #126 records different trend, but from tidal analysis comparison shows similarity with gPhone #123.

6. Acknowledgments
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